

The VIIRS Front Range Nighttime Assessment Report

Introduction

This report summarizes the assessment of a suite of Suomi-National Polar-orbit Partnership (SNPP) Visible Infrared Imager Radiometer Suite (VIIRS) products to address the detection of dust, smoke, clouds, and other obstructions to visibility at night. The assessment was conducted during July and August 2013 and used a combination of single channel and red-green-blue (RGB) composite product VIIRS imagery, which are described in detail in the products description section. The assessment included the participation of four National Weather Service (NWS) Weather Forecast Offices (WFOs) spanning three NWS regions. The offices included Albuquerque, New Mexico (Southern Region), Boulder, Colorado and Cheyenne, Wyoming (Central Region), and Great Falls, Montana (Western Region). Collectively, these four offices are part of the Front Range collaboration.

The Front Range collaboration was developed in 2013 as a joint project between NASA's Short-term Prediction Research and Transition center (SPoRT), the participating WFOs listed above, and the Colorado Institute for Research in the Atmosphere (CIRA). Both SPoRT and CIRA were working to evaluate similar RGB snow cover products. Considering the similar goals and geographic concerns of the participating WFOs, the Front Range collaboration was initiated as a way to foster intra-WFO collaboration. In particular, these WFOs share relatively large areas of responsibility, have similar forecast issues, and have limited radar coverage as well as a lack of other conventional observations. The process works as a "buddy system" where instead of one office evaluating a product in isolation, several partners contribute on a similar project.

This collaboration has continued between SPoRT and the four Front Range WFOs with the application of VIIRS products for improved situational awareness at night. The motivating factors for this assessment were to demonstrate the utility of the VIIRS products for night-time applications and to further establish the Front Range partners as a core group of WFOs to assess the applications of SPoRT RGB products. Given the Front Range collaborator's high reliance on satellite-based products compared to other SPoRT partners in the Southeast (due to more data sparse county warning areas), the Front Range partners are good collaborators for satellite-based assessments. The earlier snowfall RGB assessment established the appropriate data feeds to these offices and the VIIRS nighttime assessment

took advantage of this effort to transition several new products, as will be described in the products section.

The timeframe for the assessment was selected to correspond to the participating WFOs' fire weather season to observe smoke plumes as well as other atmospheric features at night. In particular, the VIIRS DNB single channel radiance and reflectance products, as well as the corresponding RGBs, would be used to diagnose smoke plumes and other nighttime features, such as cloud layers and thickness. The dust RGB would be used, as the name suggests, for tracking dust plumes in the region. However, no dust events occurred during this evaluation. Additionally, the nighttime microphysics RGB would be assessed for its ability to diagnose cloud features (e.g., depth, water versus ice particles, fog, etc.) as well as how it interrelated with the DNB products. Lastly, SPoRT transitioned the basic VIIRS 3.9 and 11 μm infrared channel swaths for comparison to the other products and as a contrast to the lower resolution GOES imagery.

Numerous preparations were made for the assessment to ensure product availability in AWIPS and end user understanding of the products (i.e., through training). This took the form of science sharing calls and Quick Guides sent to the four WFOs. The Front Range WFOs also had access to an online survey form to submit responses after specific events. The VIIRS Front Range nighttime assessment also had three additional constraints that should be noted. First, WFO Boulder was undergoing their AWIPS II performance evaluation. As such, SPoRT could not transition the VIIRS data to AWIPS II for the assessment. Although not ideal, SPoRT provided a web page with the high-resolution VIIRS data for WFO Boulder to use. Secondly, the assessment occurred while the NWS was within a hiring freeze. This meant that all four partner WFOs were short-staffed which would limit the time that forecasters had to focus on external activities above and beyond their day-to-day job requirements. Lastly, the fire season was relatively mild for the Front Range WFOs. This limited the primary objective of assessing the VIIRS products with smoke plumes, but SPoRT and the Front Range partners shifted the emphasis to evaluating the other uses of the VIIRS products at night, particularly with the nighttime microphysics RGB.

Product Description

Eight satellite products were included in the evaluation, although the dust RGB had no events to evaluate. As stated in the Introduction, these were made available in AWIPS for the Front Range offices. This maximized the utility of these products for operational uses as they can be readily combined with

other data sets available to the forecasters in their office. The only exception was WFO Boulder. As they were undergoing their AWIPS II performance evaluation, their office was not allowed to ingest non-baselined products. Four of the products were single channel imagery from VIIRS. These included the 3.9 and 11 μm infrared imagery and the VIIRS day-night band (DNB) radiance and reflectance products. The 3.9 and 11 μm infrared imagery commonly used for fog and cloud detection at night were used as a “control” products given their availability on the current GOES Imager (although at reduced spatial resolution). The improved spatial resolution from the VIIRS served as a good proxy for the imagery from the GOES-R Advanced Baseline Imager (ABI) instrument and demonstrations of imagery from operational Joint Polar-orbiting Satellite System (JPSS) VIIRS imagery. Given that these products were not an operational baseline product, SPoRT provided training on each of these products, as outlined in the Methodology section.

Much emphasis in the evaluation and product assessment was placed on the VIIRS low-light channel (a.k.a. DNB), which provides nighttime imagery of reflected moonlight from clouds and other features, and captures emitted light sources at nearly the resolution of day-time visible imagery. SPoRT provides two basic DNB products to these end users; radiance and reflectance. The brightness of the clouds depends on the amount of moonlight incident on them (which varies daily with location and pass). The radiance product is a calibrated and scaled image of emitted and reflected energy at visible wavelengths. It is normalized by the amount of available moonlight (based on phase and elevation angle) for every pixel in the image to obtain a scaled reflectance product. The normalization provides a more consistent brightness in the resulting image from one day to the next throughout the moon cycle. An example of the VIIRS DNB radiance product and corresponding 3.9 micron imagery are shown in Figure 1a and 1b, respectively.

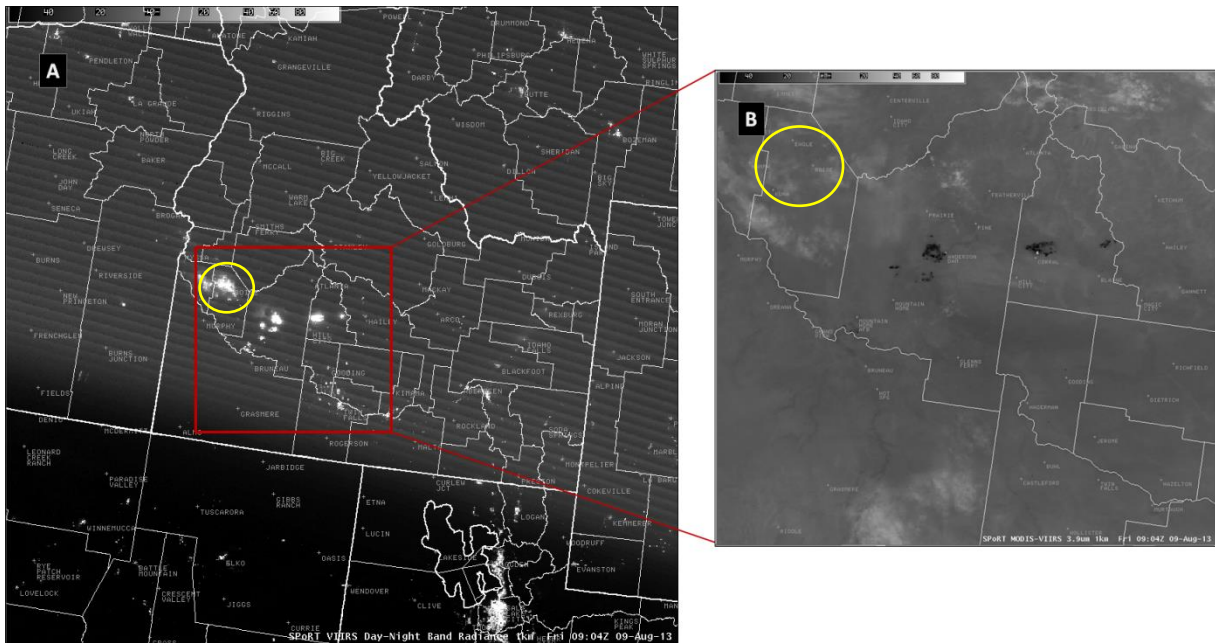


Figure 1. A sample image of the VIIRS DNB radiance product (A) at 0904 UTC on August 9, 2013. The red box indicates the zoomed in region of the VIIRS 3.9 micron image (B) at the same time in. Both images highlight fires (light emission in the DNB and thermal emission from hot spots) in white (A) and black (B), respectively. The yellow circle highlights the city of Boise, Idaho, which is observed in the DNB radiance (A), but not in the 3.9 micron image (B). These images are courtesy of the Great Falls WFO, although this particular event occurred outside their county warning area in Idaho.

A red-green-blue (RGB) composite radiance and reflectance product was produced and provided to end users for evaluation. An example of the radiance RGB is shown in Fig. 2. The DNB imagery is used for the red and green components with the VIIRS 11 micron thermal channel as the blue component. This RGB composite relies on the high sensitivity of the low-light sensor and the ability of the infrared channel to detect cloud top height. The RGB products use the thermal infrared channel to infer the cloud height via temperature, while retaining the high-resolution texture and cloud type. This composite results in better detection and delineation of many cloud features throughout the atmosphere as well as surface features than single channel imagery alone. The range of detectable features can make image interpretation complicated, however with some training the resulting RGB composites can be used to detect lights, ice and snow, and lightning as shades of yellow. Low level clouds are yellow shades with thicker clouds being a brighter yellow. Mid- to high, thick clouds are blue shades to white in appearance. Lastly mid- to high, thin clouds are blue shades. Just like the basic DNB reflectance, the DNB reflectance RGB may saturate in stray light regions due to the normalization process.

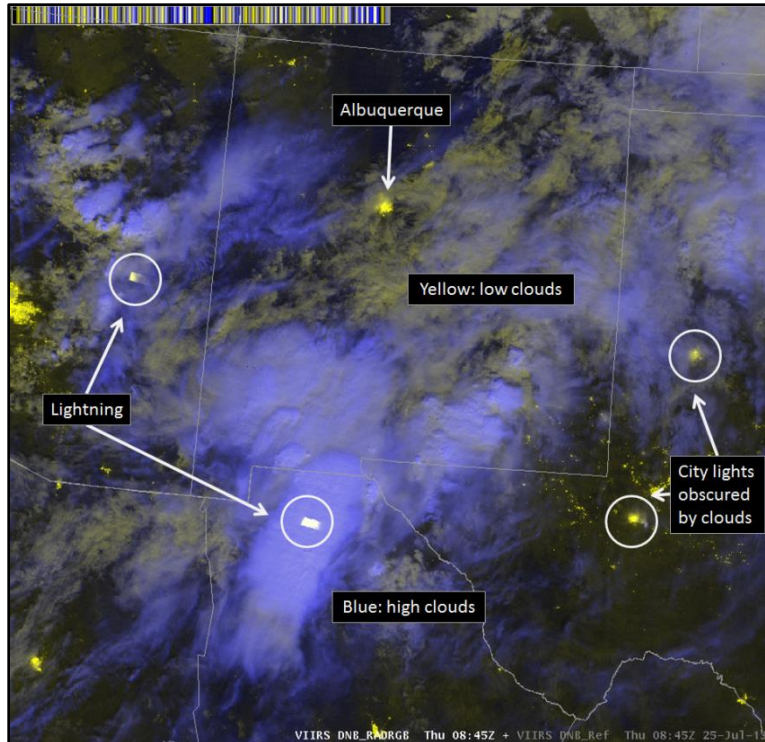


Figure 2. An example of the VIIRS day-night band radiance red-green-blue composite image from 0845 UTC on 25 July 2013. The image is over the Albuquerque County Warning Area and surrounding regions and the annotations show several relevant features.

The other RGB product evaluated was the nighttime microphysics RGB (Fig. 3). The nighttime microphysics goes beyond the basic spectral difference product (10.8 minus 3.9 micron channel) that is used to distinguish between low clouds and fog. The nighttime microphysics RGB adds another channel difference to indicate cloud thickness as well as repeats the use of the 10.8 micron thermal channel to enhance areas of warm clouds where fog is more likely. The advantage is a potentially superior method to observe fog as well as providing additional information about cloud type and composition. For the nighttime microphysics RGB, the red contribution comes from the 12 minus 10.8 micron channel difference. Physically, this relates to optical depth, which has a low contribution for thin clouds and a high contribution for thick clouds. The green contribution is the traditional spectral difference composite of the 10.8 minus 3.9 micron channels, which relates to the particle phase and size. In situations with ice particles or a cloud-free environment there will be little contribution. The high contribution occurs with water clouds that have small particles. Lastly, the blue contribution comes from the 10.8 micron thermal channel to observe the temperature of the surface. Cold surfaces contribute little to the blue component, while warm surfaces have a large blue contribution.

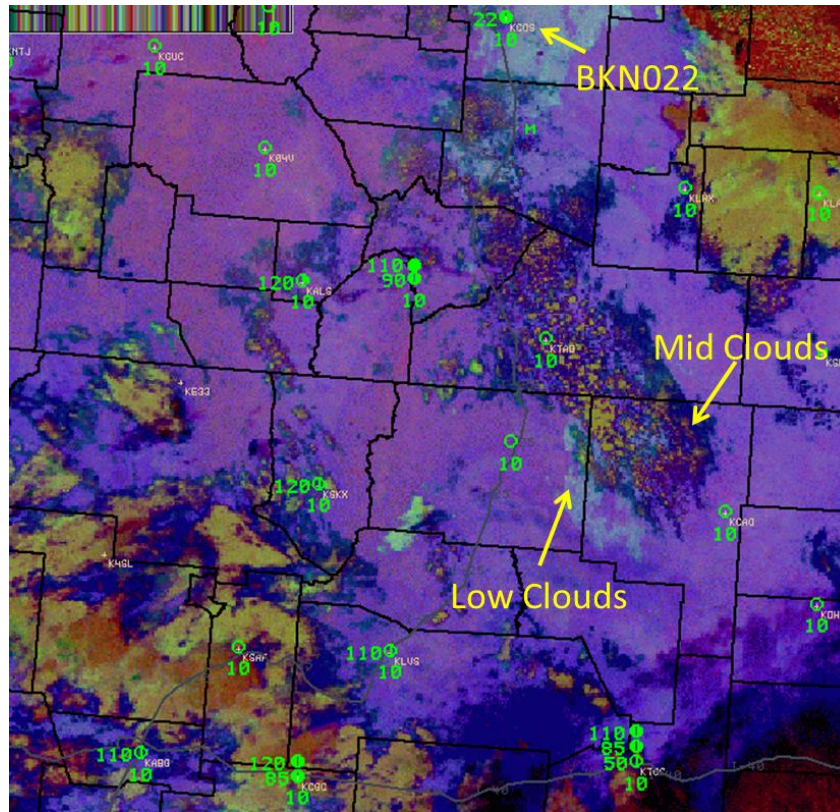


Figure 3. A sample image of the VIIRS nighttime microphysics red-green-blue composite from the Albuquerque Weather Forecast Office highlighting regions of low and mid clouds at 0816 on August 1, 2013.

The VIIRS imagery was generally available once a night around 0830 UTC. However, the wide swath width of VIIRS and a favorable orbital track occasionally provided a second pass around 1015 UTC for the Front Range partners. In order to help supplement the VIIRS imagery, observations from the Aqua and Terra Moderate Resolution Imaging Spectroradiometer (MODIS) instruments were included in this assessment. While not an exact match for the VIIRS channels, MODIS data were used to add additional observations of long and shortwave IR imagery, as well as the nighttime microphysics RGB. With the Aqua and Terra overpasses, the Front Range Partners generally could expect two to four overpasses of the four products mentioned each night.

Methodology

The VIIRS Front Range nighttime assessment was conducted to evaluate the nighttime applications of the VIIRS instrument to address reductions in visibility due to smoke, dust, clouds and other obstructions and to improve general situational awareness at night when the use of GOES

infrared satellite data alone makes it more difficult. This approach relied on several VIIRS features ranging from superior spatial resolution to current GOES imagery, additional channels with which to make the RGB products, and the unique DNB channel. The timeframe focused on the main fire weather season of July through August.

A key focus for this assessment was to evaluate the utility of these VIIRS products at night. The Front Range WFOs have a combination of limited radar coverage and other in-situ observations that creates under-observed or data void locations within their county warning areas. New satellite-based observations could greatly enhance the ability to diagnose conditions that would otherwise be more difficult. The nighttime component was specifically targeted as the WFOs are essentially limited to lower resolution infrared and water vapor channels from GOES at night, as compared to the visible channel during the day. More specifically, this assessment focused on several nighttime forecast needs. First, the DNB products would be used to identify fire hot spots, in comparison to the lower resolution GOES 3.9 μm channel as well as identifying smoke plumes. The ability to detect plumes at night would be valuable to update air quality statements, visibility reports for terminal aerodrome forecasts, and qualitatively assess the fire's progress. Furthermore, the DNB products have improved spatial resolution compared to the current GOES IR imagery. The DNB RGBs, along with the nighttime microphysics RGB would be evaluated to infer storm and cloud dynamics, as well as fog potential, in these data sparse regions.

Given that the assessment used several new products and concepts, SPoRT prepared a number of training tools to help prepare the Front Range WFOs. Three science sharing telecons were conducted. These included a formal module presented by SPoRT and allowed for a live question and answer session between SPoRT and the WFOs. These questions focused on the uses and interpretation of the VIIRS products. Three sessions were selected in order to provide multiple opportunities for forecasters to attend in order to account for the operational shift schedules. In addition to the live training, a series of Quick Guides were provided to the participating WFOs. This single-page, front and back document was laminated and intended to be used on the operations floor next to a forecaster's work station. The concept follows the idea of "just in time" training. Instead of a long document, the Quick Guides provide the basic "how, what, and why" of a product. As a result, if a forecaster has a question, the Quick Guide can be used to rapidly address a particular concept. For this assessment, four quick guides were available. These included a basic VIIRS overview, the VIIRS DNB, and a Quick Guide

for the nighttime microphysics RGBs. Appendix A provides the web links to the electronic version of these Quick Guides.

In addition to these preparations prior to the assessment, SPoRT informed the participating WFOs of different routes with which to submit feedback. The main mechanism for feedback was an online survey page hosted through Google Documents. This method was very simple for SPoRT to develop and implement as well as provided evaluators an easy form to provide thoughts and feedback. The questions are available in Appendix B. The objective of the survey form was to create a 2 minute survey that was simple and fast for forecasters to complete. The survey had to be unobtrusive as SPoRT recognizes the limited amount of time forecasters may have on operational shifts. The survey is designed to glean higher level, but more quantitative results. The questions were designed to assess the training the forecaster had taken, determine the specific event being evaluated (as not all of the products being assessed would be used simultaneously), and record the forecaster's view of the impact of the specific products used.

The feedback process was not limited to the online survey. SPoRT encouraged the participants to be involved with blog posts and communications with the developers (SPoRT staff) directly. One limitation of the online surveys was that forecasters could not post an image. As such, the Wide World of SPoRT Blog (<http://nasasport.wordpress.com/>) provided a vehicle with which to graphically demonstrate the nighttime uses of VIIRS products during the assessment. SPoRT personnel could also post interesting events they observed to share with the forecasters. Another advantage of the blog was that it served as informal science sharing between the participating WFOs as well as other organizations that viewed the blog. The participating forecasters were also encouraged to communicate with the SPoRT team with any questions or comments via e-mail or phone conversations. Likewise, SPoRT followed up on each survey response with an e-mail message to the responder. These communications allowed for follow-up discussions that could investigate operational uses and needs in more detail and to ask more quantitative questions. These communications served to clarify questions that may have arisen in the survey responses so as to ensure the intended meaning of the response was clear.

Combined, these response methods provided the forecasters with multiple avenues to submit feedback on the use of these VIIRS products. These ranged from the formal survey questions, the graphically oriented SPoRT blog, to the informal but more detailed phone and e-mail conversations. Each method gave SPoRT and the WFO different ways to communicate feedback that fit within the

forecasters' operational time constraints but also gave SPoRT the information needed to determine how these VIIRS products were used and their potential impact on operations.

Results

The results for the Front Range assessment of the nighttime uses of VIIRS imagery has been separated into two components. The first summarizes the feedback that was received from the forecast offices. The second will show two examples from the assessment period.

Although forecaster shortage and a limited fire season reduced the scope of the product evaluation, 19 surveys were submitted. All but one response indicated that the evaluator had received training, either through the science sharing calls or use of the Quick Guides. Also, as discussed in the Methodology section, there were 7 blog posts made during the assessment period. Two blog posts were used to demonstrate the examples that occurred during this VIIRS evaluation and several were re-blogged from posts by WFO Great Falls on their own local blog page. The content ranged from interesting views of the VIIRS imagery to potential nighttime uses of VIIRS data in the operational WFO environment.

Survey Results

The traditional pros and cons of polar orbiting imagery were described in the end user responses. Specifically, the resolution was greatly appreciated, especially when compared with traditional GOES imagery. In several cases, it was noted that the resolution of the VIIRS 3.9 μm and DNB imagery provided more accurate locations for fire hot spots than GOES imagery alone. This would be invaluable for incident support during the fire and for generating a more accurate burn scar location to deal with future flash flooding threats. However, the limited number of overpasses and the times of the overpasses were detrimental. For example, the time of the VIIRS overpass was usually too early in the night to use the nighttime microphysics to monitor fog during the morning commute hours. However, the very wide swath width of VIIRS was found to help offset some of the issues associated with limited overpasses.

One series of questions asked end users about the utility of the VIIRS DNB to understand cloud features as they obscured city lights and four responses were submitted. One response did indicate that the transparency of the cloud cover could be important. Having a qualitative assessment of cloud

transparency could be used to modify temperature forecasts by inferring the amount of outgoing longwave radiation that could be trapped. In this role, the utility of the VIIRS DNB was rated low.

The surveys consistently indicated that two sets of products were the more useful than the others in operations. The first was the VIIRS DNB radiance and corresponding RGB composite products. The responses showed that the end users greatly appreciated the product's resolution. This made the radiance DNB products most useful in hot spot detections and supplementing the traditional 3.9 μm imagery from GOES. As stated above, this superior resolution more accurately indicated the burn scar locations and would be valuable for future flash flood forecasts. The higher resolution also was noted to be important in the more rugged terrain found in the county warning areas of the Front Range WFOs. Having a more accurate representation of what side of a ridge a fire was located was absolutely critical to fire weather operations. Supporting the VIIRS radiance DNB products was the VIIRS, high resolution 3.9 μm channel. Like the DNB, forecasters ranked this VIIRS channel highly when compared to GOES for the resolution and the ability to supplement the DNB hot spot locations.

Another response for the VIIRS DNB radiance products was to assess, qualitatively, the growth of a fire. The responses indicated that the brightness of the fire hot spot and the overall size could roughly provide feedback on how the fire was evolving. One recommendation was to color code the fire hot spots so that they appear different from city lights. This was considered more useful than detecting fire smoke plumes, which was observed in only one of six cases.

Lastly, the VIIRS DNB single channel radiance and its associate RGB composite were preferred over the related VIIRS DNB reflectance products. This was primarily due to the radiance product not normalizing the amount of light being observed as in the reflectance product. In cases of poor lunar elevation angle or phase, other light sources could saturate the reflectance image. The radiance, which was more of a raw observation, did not appear to have as serious of a drawback with this.

Beyond the VIIRS DNB radiance products, the nighttime microphysics RGB composite was, by far, the most useful product. In the surveys the nighttime microphysics RGB received responses of high or very high for its utility. This was especially true for assessing cloud type and cloud features in the region. The resolution at which VIIRS provided the nighttime microphysics RGB was another strong capability in this product's favor. Many of the surveys expressed a continued interest in receiving these observations as part of both the GOES-R and JPSS proving grounds. The nighttime microphysics RGB will

be highlighted in the examples below. To summarize, the RGB product was used to examine a number of cloud features.

- Mid-level clouds: Supplemental observations where traditional GOES did not clearly observe thick, mid-level clouds in a poor radar region that had surface observations of rain.
- Detail the structure and organization of a remnant mesoscale vortex that modes struggled to handle.
- Monitor previous convection to assess the likelihood of new convection the next day.
- Provided a more clear analysis of low clouds in the region and was more effective than the basic VIIRS DNB.
- More detail to observe fog as well as fog and low cloud regions.

A limitation indicated by the forecasters in the surveys stated that additional training was necessary to fully understand how to interpret the nighttime microphysics RGB composite product. The training requirement was requested as the multi-colored nighttime microphysics RGB product was not immediately intuitive and would require time for the forecasters to fully synthesize these observations into operations. In spite of this limitation, the majority of surveys indicated that the end users do wish to continue integrating this product into operations. Subsequent feedback from these WFOs since the summer 2013 evaluation have stated that confidence has continued to grow in the use of the nighttime microphysics RGB and the product continues to develop support within the WFOs. This product also is now the focus of a 2014 Visiting Scientist Program effort between SPoRT and WFOs Albuquerque and Great Falls.

The surveys also highlighted several other items. One was the observation of smoke plumes at night. Given the quiet fire season, only six surveys were submitted regarding this VIIRS DNB capability. Of these six, the smoke plume was only observed once, which led to a negative view of the utility of the VIIRS DNB for this particular use. In the case where the smoke plume was observed, it was through indirectly observing the obscuration of city lights by the plume; a feat not possible with the current GOES imagery. SPoRT investigated what may have caused the inability to detect the smoke plumes and determined two potential causes for this lack of detection. For one case, high clouds obscured the smoke plume. In a second case, the angle of the VIIRS overpass was not favorable for observing the smoke plumes. For the remaining three cases, SPoRT determined that there was limited or no moonlight to reflect off of the smoke. Additionally, the image enhancement available during the

assessment time period did not properly bring out the subtle features in the radiance or reflectance products to observe the smoke plumes. This was noted in a free form response that indicated that smoke plumes were difficult to detect as the reflectance product appeared “over saturated”. SPoRT, in response to this feedback, has since adjusted the image enhancements to the image display for the DNB products now being generated by SPoRT’s end users. While the feedback was overall negative for using the DNB to detect smoke plumes, the WFOs are interested in re-evaluating this capability with the improved image enhancement. The interest is to use this in combination with the DNB hot spot detections to observe the extent and location of the smoke plume in order to enhance visibility, air quality, and terminal aerodrome forecasts as well as to aid with impact-based incident support.

There was one final survey response that did not fit any of the other situations above. In this case, the office was observing the high resolution 11 μm imagery. The survey stated that, “The VIIRS imagery provided significantly more enhanced detail of the rapidly cooling cloud tops on severe storms across northeastern New Mexico. The brightness temperature observed from the VIIRS image was - 85°C, which was more than 10 degrees colder than the GOES imagery.” The forecasters and Warning Coordination Meteorologist were impressed with this observation as this was significantly colder than had been observed using GOES previously. This particular example demonstrates the utility of the high resolution VIIRS imagery to serve as a precursor for the future GOES-R Advanced Baseline Imager.

Specific Events

WFO Albuquerque, 17 July 2013

This case was submitted by WFO Albuquerque on 17 July 2013. This case was of particular interest as it demonstrated the use of RGB imagery in a poor radar coverage region. Figure 4 shows the Albuquerque radar reflectivity and indicates the region of interest with the red circle (Farmington, New Mexico east-southeast of the Four Corners region). Here the lowest radar level is 15,000 feet above ground level. In Fig. 4, the Farmington surface observation is reporting light rain, but the radar has no reflectivity observations. A conveniently timed overpass of VIIRS provides a snapshot of the nighttime microphysics RGB image at 0753 UTC (Fig. 5). Here, the 1 km resolution RGB composite shows a well-defined region of mid-level cloud cover over Farmington.

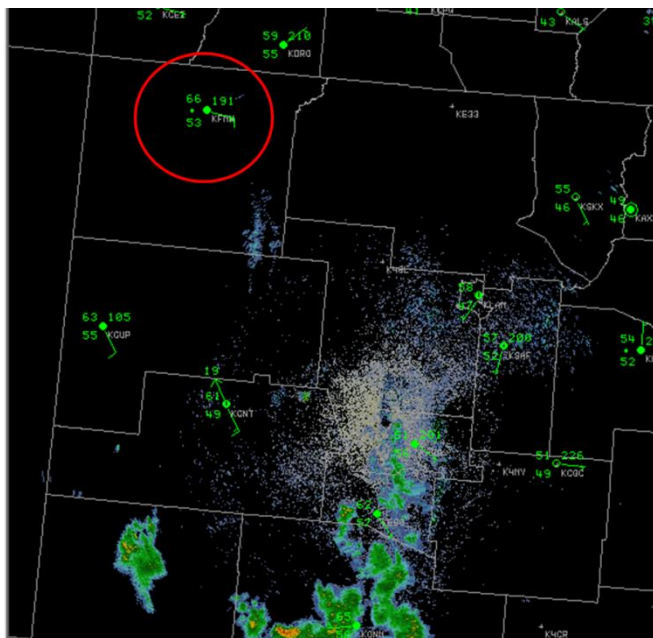


Figure 4. The Albuquerque radar reflectivity at 0800 UTC on 17 July 2013. The Farmington, NM surface observation is circle in red and shows light rain, but there is no corresponding radar reflectivity.

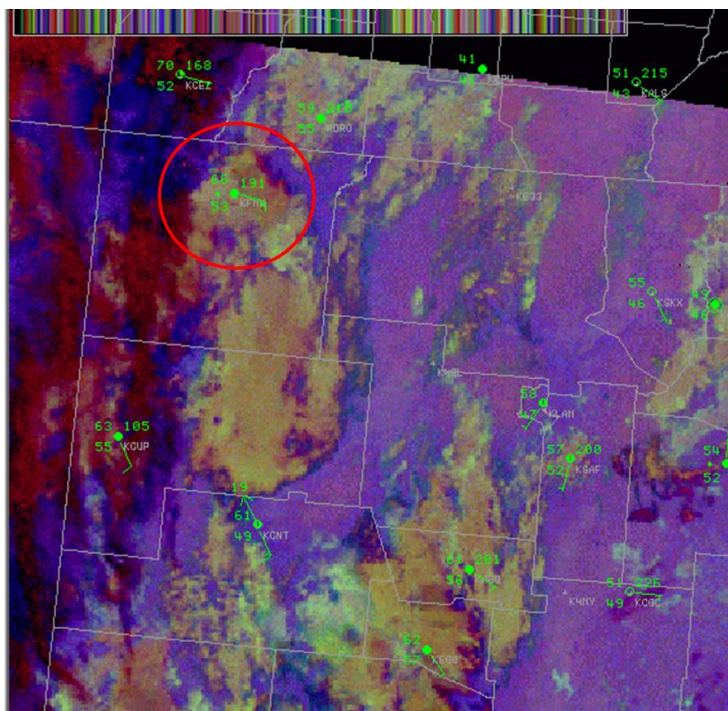


Figure 5. The VIIRS nighttime microphysics red-green-blue composite image at 0753 UTC on 17 July 2013.

With this image, the operational forecasters indicated that the nighttime microphysics RGB imagery could be used to infer where showers were likely in the region where radar observations are

poor or show no precipitation at all. The forecasters also added that the cloud cover and visibility was not enough to affect aviation interests.

WFO Boulder / Cheyenne Vicinity, 21 July 2013

This case was highlighted by the SPoRT team to the Front Range collaborators as most of the activity was outside the domain of the respective county warning areas. The case occurred on 21 July 2013 at 0821 UTC. This served as a good example case as it demonstrated four of the available products in one event.

The synopsis showed mostly clear skies over both the Boulder and Cheyenne county warning areas. The main features were a storm complex in southwestern South Dakota into north-central Nebraska and another region of cloud cover in southeastern Colorado. The analysis started with the DNB reflectance product in Fig. 6. The moon phase and elevation were extremely favorable for the DNB single channel reflectance imagery. This provided an image remarkably similar to a standard visible image. In the first part of the analysis of Fig. 6, several features stand out. First, the two main regions of storms / clouds in South Dakota (Feature 1) and southeast Colorado (Feature 2) are very clear. Secondly, given that the DNB is a low light sensor, numerous cities are visible (Feature 3). Also, a small band of clouds extends from north of Cheyenne, Wyoming into western Nebraska (Feature 4). The level is indeterminate, but the shadows cast by the clouds are clearly evident. Lastly, a very interesting curved and rippled feature is visible from northwest Kansas into eastern Colorado (Feature 5). The DNB single channel reflectance offers an excellent way to observe these features at a higher resolution than the current GOES 11 μm infrared channel. However, combined with the other products, several other determinations can be made about these features. For instance Fig. 7, observes the same region

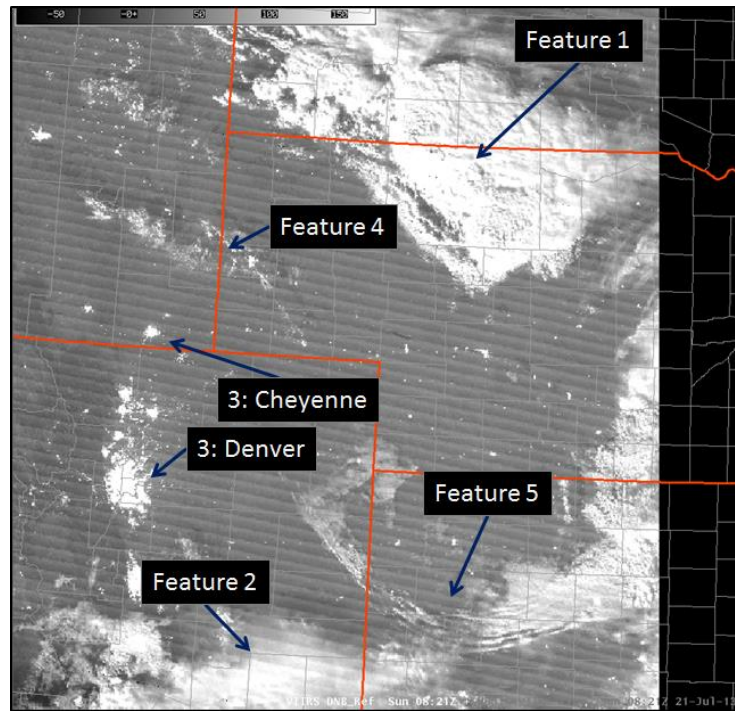


Figure 6: The VIIRS DNB single channel reflectance product over the Boulder and Cheyenne County Warning Areas and regions to the east. The five features discussed in the text are highlighted in the image. The image occurred at 0821 UTC on 21 July 2013.

and time, but with the VIIRS 11 μm IR channel at 1 km resolution. This provides a powerful example of what the future Advanced Baseline Imager, with its 2 km resolution will look like in operations. Using the VIIRS IR channel, we note several additional details about the features. First, as this is an IR image and not a low light observation like the DNB, the city lights (Feature 3) are no longer present. The IR channel also highlights the coldest cloud tops (Features 1 and 2) and specifically highlights extremely cold cloud tops in Feature 1 in north-central Nebraska. Given the resolution, Feature 1 may be more convective while Feature 2 may be cirrus over another cloud deck. The clouds in Wyoming to Nebraska (Feature 4) are observed indicating some height, but are not as cold as the cloud tops observed in Features 1 and 2. Lastly, the interesting rippled cloud structure (Feature 5) is not visible, suggesting the clouds are at low levels.

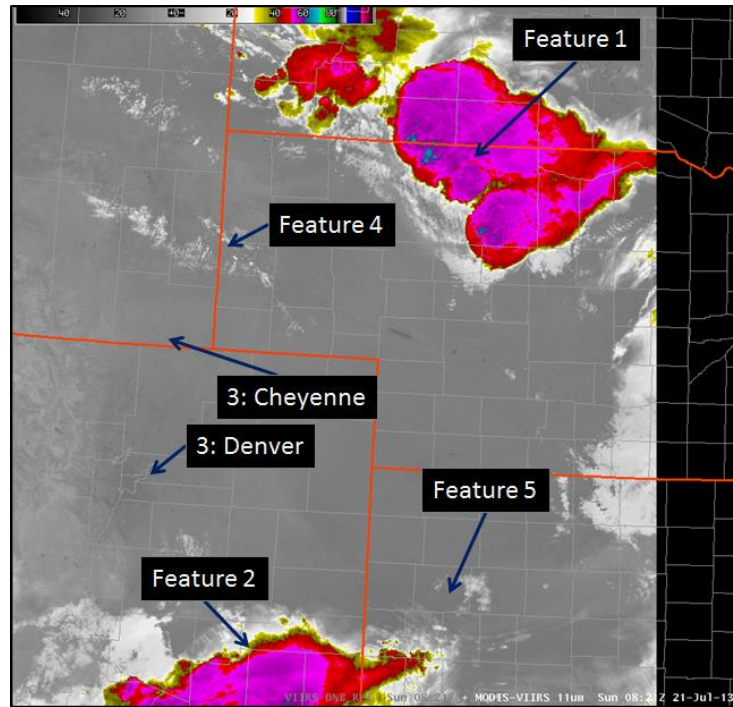


Figure 7. The VIIRS 11 micron infrared observation for the same time and region as in Fig. 6.. The same five feature locations are highlighted..

The DNB radiance RGB composite (Fig. 8) combines the basic DNB radiance (similar to the reflectance in Fig. 11) and the 11 μm IR imagery and essentially provides a single image with all of the information observed in the previous two images (Figs. 6 and 7). Surface features and the lowest clouds will appear yellow while the coldest clouds will appear blue. Thinner or mid-level clouds will be whiter in color. We observe that the conclusions from the two previous figures do hold here. Features 1 and 2 are blue suggesting high, cold clouds. Feature 1 also has several streaks in it due to lightning flashes. These flashes confirm the convective nature of these storms suggested by the IR image alone. The city lights (Feature 3) are again visible and will appear yellow along with the curved and rippled cloud structure in Feature 5. This supports the IR only image that this cloud structure is composed of low level clouds or possibly fog. The clouds in Wyoming (Feature 4) have a white-blue color suggesting mid-level or potentially thinner clouds.

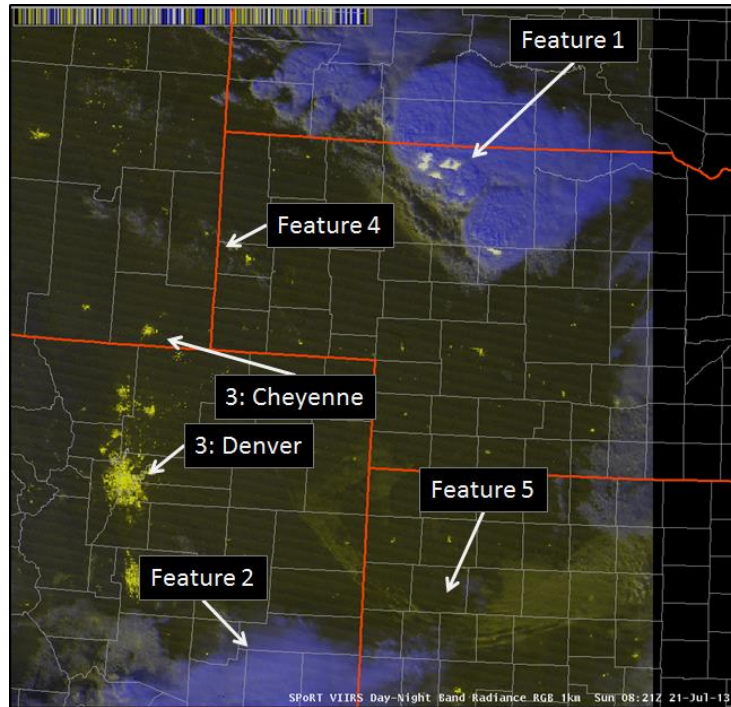


Figure 8. This observation occurred at the same time and location as Fig. 6, but now shows the VIIRS DNB radiance RGB product along with the features originally highlighted in Fig. 6.

At this stage, these products provide a good generalization of the situation. However, a couple questions remain. These include whether or not Feature 2 is cirrus or thicker cumulus clouds, the composition of Feature 4, and whether or not Feature 5 is a low cloud or fog. These can be addressed with the nighttime microphysics RGB composite.

The nighttime microphysics RGB composite is shown in Fig. 9. Using the channel combinations described in Product Description section, the nighttime microphysics can provide greater detail on the level of the clouds, their thickness, and general composition. To start Features 1 and 2 stand out as very red. This confirms again the thick, convective nature of Feature 1. Further, it indicates that Feature 2 is composed of optically thick clouds and not a thin cirrus shield alone. Again, as this is not the DNB, the city lights (Feature 3) are not observed. The band of clouds in Wyoming to Nebraska (Feature 4) have a stronger blue component indicating they are a lower than Features 1 and 2. These are likely mid-level clouds. Finally, the undular bore structure (Feature 5) is primarily a whitish blue. This indicates the clouds are relatively thin and warmer than the surrounding clouds. Furthermore these are low level clouds and not fog, which would be whiter as it would be influenced more by observations bleeding through from the surface. Additionally, Feature 1 shows a narrow band of clouds on the southwest

sharing the same observational combination as Feature 5. This is likely a developing outflow from the active convection.

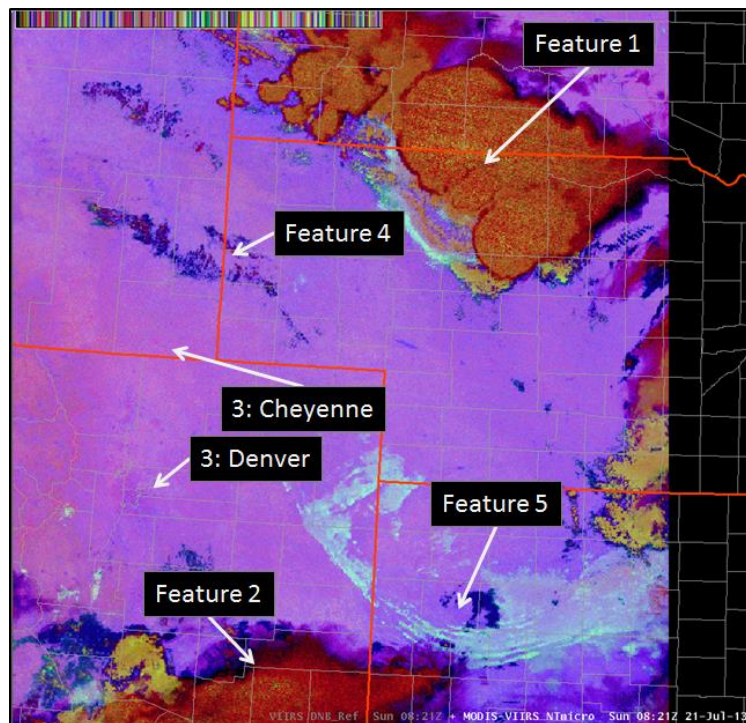


Figure 9. This observation occurred in the same location as Fig. 6, but shows the VIIRS nighttime microphysics RGB product along with the same features highlighted in Fig. 6.

Summary and Recommendations

The Front Range effort is a collaboration that incorporates NASA SPoRT, CIRA, and the Albuquerque, Boulder, Cheyenne, and Great Falls, Montana Weather Forecast Offices. The Front Range collaboration was initiated to bring together partner WFOs with similar forecast needs and concerns and spanning multiple National Weather Service Regions, specifically the Southern, Central, and Western regions specifically. Each WFO has similar issues with poor radar coverage and a strong reliance on satellite-based observations.

When the opportunity came to establish an evaluation as part of the JPSS proving ground for the VIIRS nighttime imagery, the Front Range collaboration was the immediate choice. The intensive evaluation period took place over July to August 2013. Eight separate products were evaluated. These included two single channels from VIIRS; the 3.9 and 11 μm imagery. The VIIRS DNB provided four products. These were the single channel radiance (raw low light observations) and reflectance

(normalized low light observations) as well as a radiance and reflectance RGB composite that combined the DNB channel with the 11 μm channel. Lastly, an RGB composite for dust and nighttime microphysics was evaluated. For this survey, no dust events occurred with which to evaluate the dust RGB.

The feedback from the surveys showed that two products were considered the most beneficial to operations. These were the VIIRS DNB radiance product (both the single channel and RGB composite versions) as well as the nighttime microphysics RGB. The main reasons given by the end users were the superior resolution of these products, which is particularly beneficial for fire hot spot locations and the ability to identify cloud type and features with the nighttime microphysics RGB. Ultimately, the nighttime microphysics RGB received the greatest positive response for its use in operations. The combination of high resolution and being able to investigate cloud features, dynamics, and structure led to this product being rated high to very high.

The survey responses indicated a great deal of interest to continue to incorporate these specific products into operations. The fact that the VIIRS nighttime microphysics served as a “sneak peek” at future GOES-R capabilities with the Advanced Baseline Imager, generated additional interest in this product. Forecasters did indicate that additional training was required, but that did not prevent the forecasters from highlighting the potential of this VIIRS product. Other recommendations included a change to color code fire hot spots and city lights differently in the VIIRS DNB radiance product. This would allow forecasters to more easily distinguish between one and the other.

Following the NASA SPoRT paradigm of matching products to a forecast issue, producing training, and then conducting an assessment, SPoRT will use this feedback to develop plans for the follow-on assessment to these products. The request for additional training examples will be a major emphasis. Additionally, there are plans for a 2014 evaluation to generate a more robust survey data set as external factors limited participation in 2013. Also, there were no cases to observe the dust RGB during this Front Range assessment. Furthermore, SPoRT addressed an issue with the VIIRS DNB image enhancement that limited the utility of this product to observe smoke plumes. The 2014 evaluation will provide SPoRT the opportunity to re-evaluate these products with a user base that is more familiar with them and has had additional training. This will allow all of the collaborators to determine how to continue to incorporate these specific products into operations.

Appendix A

The web links to the Quick Guides used for training in this assessment are provided here.

VIIRS Overview:

<http://weather.msfc.nasa.gov/sport/training/viirs/VIIRS%20quick%20guide%20NASA%20SPoRT.pdf>

VIIRS Day-Night Band:

<http://weather.msfc.nasa.gov/sport/training/viirsDnb/VIIRS%20DNB%20quick%20guide%20NASA%20SPoRT.pdf>

Nighttime Microphysics Red-Green-Blue Composite:

http://weather.msfc.nasa.gov/sport/training/rgb_ntmicro/RGB%20Nighttime%20Microphysics%20Reference%20Guide.pdf

Appendix B

The survey questions used in this assessment are presented here for the reader.

Basic Information

NWS Office:

Name (Optional):

E-mail (Optional):

Event Date:

Time of Shift:

Please indicate whether you have received training on the products in this assessment.

Mark the condition where you used the VIIRS imagery/products at night, then answer the subset of feedback questions. (Note: The response here would then take the responder to the appropriate sub section below.)

Smoke Plumes and Fire Hot Spots

1. Was the smoke plume detectable by the DNB imagery? (Yes or No)
2. If smoke plumes were detected in VIIRS imagery, was the direction of the smoke plume consistent with the direction of low level winds indicated by model data? (Yes or No)
3. Which DNB product was most useful in detecting smoke plumes and / or fires?
4. Rate the application value of the DNB imagery to monitor smoke plumes compared to other data / information sources in operations.
5. Rate the DNB imagery impact to decisions and / or WFO issued products related to smoke plumes at night in your region.
6. Rate the value of the VIIRS 3.9 μm imagery to detect hot spots compared to standard GOES imagery.
7. If able, briefly (~3 sentences or less) state why it was or was not useful to apply VIIRS imagery at night for monitoring smoke plumes and hot spots.
8. What change in the data or its display would you like to see, if any?

Change in City Lights and Other Emissions

1. Which DNB product was most useful to examine light emissions at night?
2. Were the city lights or other surface sources obscured?

3. If you answered yes to #2, what did this tell you about the clouds in the area? The clouds were...
4. Were lightning flashes detected with the DNB? (Yes or No)
5. What other emission sources did you examine and why? This might include things like ships, oil or gas wells, fire hot spots, etc.
6. Were power outages evident by examining the DNB imagery? (Yes or No)
7. If yes to #6, what action was taken as a result?
8. Rate the value of the VIIRS DNB imagery to diagnose surface light emissions.
9. If able, briefly (~3 sentences or less) state why it was or was not useful to apply VIIRS imagery at night to examine surface light emissions.
10. What change in the data or its display would you like to see, if any?

Cloud Type, Height, and Structure

1. Which products were examined to diagnose cloud type, height, and / or structure? (Check all that apply)
2. Which product had the most utility?
3. State the cloud feature or cloud type being examined.
4. Rate the DNB imagery impact to decisions and / or WFO issued products related to diagnose cloud features at night in your region.
5. Rate the value of the VIIRS imagery to diagnose cloud features compared to standard GOES imagery.
6. If able, briefly (~3 sentences or less) state why it was or was not useful to apply VIIRS imagery at night for cloud analysis.
7. What changes in the data or its display would you like to see, if any?

Dust Aloft

1. Was the dust event detectable by the VIIRS dust RGB imagery? (Yes or No)
2. For this event, which dust RGB product did you find most valuable?
3. Rate the application value of the VIIRS dust RGB imagery to monitor dust aloft compared to other data / information sources in operations.
4. Rate the VIIRS dust RGB imagery impact to decisions and / or WFO issued products related to dust aloft at night in your region.
5. Rate the ability to differentiate the height of the dust aloft at night using the VIIRS dust RGB imagery and color table from the Quick Guide reference.
6. If able, briefly (~3 sentences or less) state why it was or was not useful to apply VIIRS imagery at night for monitoring dust aloft.
7. What change in the data or its display would you like to see, if any?

Other Events

1. State which VIIRS product was evaluated.
2. What was the feature that was being examined?
3. Describe if the VIIRS imagery was able to provide value and if so, how.